EXPERIMENTAL INVESTIGATION OF THE FLOW OF STEAM THRU PIPES BY MEANS OF THE PITOT TUBE

BY

L. G. FRIEDLANDER and C. F. BUSSE

Armour Institute of Technology

1908

533
F 91

Illinois Institute
of Technology
UNIVERSITY LIBRARIES

AT 114
Friedlander, L. G.
Experimental investigation
of the flow of steam thru

For Use In Library Only

AN EXPERIMENTAL INVESTIGATION OF THE FLOW OF STEAM THRU PIPES BY MEANS OF THE PITOT TUBE

A THESIS

PRESENTED BY

L. C. FRIEDLANDER

CLAYTON F. BUSSE

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

ILLINOIS INSTITUTE OF TECHNOLOG
PAUL V GALVIN LIBRAR
35 WEST 33RD STREE
CHICAGO, IL 60616

F. Gebhardt
L. C. Monin,
Dean of the Cultural Studies.

H M Raymond
Dean of Eng Studies

CONTENTS.

Page

Bibliography . . . . 50-51.

Conclusions . . . . 49.

Curves Obtained with the First Form of Pitot Tube Used . . . . . . 42.

Curves Obtained with the Second Form of Pitot Tube Used . . . . . . 43.

Description of Apparatus . . . . 3-4-5 .

Description of Gage Glass Instrument . . . . 6.

Description of Burnham Pitot Steam Meter . . 6-7.

Discussion . . . . 46-47-48.

Log Forms . . . . 14 to 41.

Method of Operation . . . . 8-9-10.

Object of Thesis . . . . 1.

Running Logs. . . . . 14 to 31.

Theoretical Curves for 3 in. pipe . . . . . 44.

Theoretical Curves for 4 in. pipe . . . . .45.

Theory. . . . . 11- 12- 13.

20760

ILLUSTRATIONS.

Page

Blue Print No. 1 . . . . 54.

Blue Print No. 2 . . . . 55.

Cut showing Setting of Apparatus . . . . A.

Cut showing Back of Meter . . . . . . B.

Cut showing System of Piping . . . . . C.

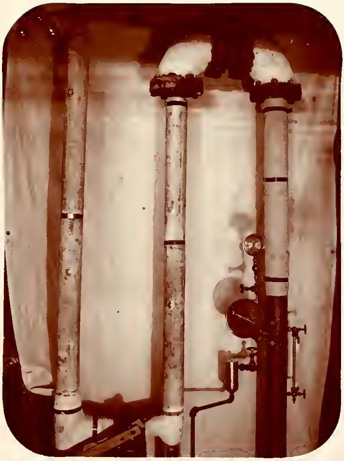
Fig. 1 . . . . 52.

Fig. 2 . . . . 52.

Fig. 3 . . . . 52.

Fig. 4 . . . . .53.

Fig. 5 . . . . 53.



THE FLOW OF STEAM THRU PIPES.

This thesis is an experimental investigation of the flow of steam thru pipes by means of the Pitot tube.

The Pitot tube was first used by its inventor, Pitot, in 1837, and by those who followed him in the measurement of the flow of water. Afterwards it was used to measure the flow of air and other gases. Many exhaustive experiments have been made to determine the equation of the Pitot tube, and the effect of the variation of the shape of both the bent and the pressure tube. We refer those who are interested in these developments to a bibliography following, in which we have noted the best articles on this subject by recognized authorities. However we have very little data on the subject of the use of the Pitot tube for the measurement of the flow of steam thru pipes, especially where the condensed steam itself is used as a self adjusting head.

Two instruments were used to obtain the rate of the flow of steam; one, a set of Pitot tubes con -

nected to a gage glass in which the velocity head was visible; the other instrument being a brass chamber connected to another set of Pitot tubes , and containing a glass float, which , rising and falling with the change in the velocity head , recorded its height thru a mechanism to a hand travelling over a graduated dial. The object of our experiments with the latter instrument , which we shall designate as a steam meter , was to obtain curves showing the relation between the rate of flow per hour and the readings of the dial hand in degrees , for different steam pressures and different sizes of pipes. Our object in using the gage glass was to obtain the relation between the theoretical velocity corresponding to the velocity observed from the gage glass , and the actual average velocity obtained by dividing the actual flow by the area of the pipe in square feet.

The arrangement of the piping used to obtain the flow of steam may be seen from blue print No.1. It was so designed as to deliver dry and saturated

steam. The drains "G" and "E", placed before the meter were left open continually so as to relieve the system of any water that may have collected in it. The valve "A" placed just before the meter was a 2 inch globe valve, to which was attached a wooden handle for the sensitive adjustment of the pressure. By means of this valve the boiler pressure was throttled down to the desired pressure. As there was a liability of having superheated steam due to this throttling of the boiler pressure, a Carpenter calorimeter was inserted after the meter to determine the quality of the steam passing the meter. The meter carried a 3 1/2 inch A. S. G. & V. Co. Bourdon gage No. 608 R 784, thecalibration of which will be found at the end of this article. The valve "B", also a 2 inch globe valve, was used to regulate the flow of steam thru the meter. After passing the valve "B", the steam passed thru a Wheeler condenser, having a condensing surface of 200 square feet, from which the condensed steam was pumped into large weighing tanks and weighed.

The gage glass instrument consists of a bent Pitot tube as shown by Fig. 5 , and a pressure tube as shown by Fig. 4 . The bent tube is inserted in the pipe , thru which the flow of steam was to be measured , so that the center of the bent part of the tube was at the center of the pipe . These tubes are placed about 12 inches apart, and are connected to the gage glass by fittings. Running along the side of the gage glass is a steel scale graduated in tenths of a inch , from which velocity heads up to 10 inches may be measured. The construction of the scale is such , that the zero of the scale may be set to coincide with the zero position of the velocity head . There are valves at the top and bottom of the gage glass , which are used to throttle the velocity head in case there is excessive vibration of the water in the gage glass .

The steam meter consists essentially of a brass chamber containing a glass float , which rises and falls with the change of the velocity head. The float is attached to an arm which revolve about a shaft , as shown by blue print No. 2 . This

by means of a connecting rod , moves a sector with teeth , which in turn moves a pinion on whose shaft is a permanent magnet . Now outside of the casing is another smaller magnet , whose movement is controlled thru the brass casing by the heavier inner magnet . Connected to the shaft of the outer magnet is an aluminum hand which traveles over a dial graduated in degrees . The meter is connected to the Pitot tubes at the top and the bottom of the meter casing , by means of ground union joints. The lower or bent tube is so placed as to face the flow of steam at the center of the pipe . The pressure or upper tube protrudes about 1/4 inch in the pipe . The ends of all pressure tubes used were cut off at an angle of 30 degrees so as to overcome the effect of aspiration due to the velocity of the steam thru the pipe . (See Figs. 2 & 4 .) The bent Pitot first used with the meter is shown in Fig. 1 , and the curves obtained with this form of tube are shown on page 42. Afterwards a change was found to be advis-able , and the form of the new tube will be found on Fig. 3 , and the curves

obtained with this form of a tube are shown on page 43. The pressure gage was connected to the meter , by means of a pipe tapped in the top of the meter casing , as shown by blue print of meter , thus giving the pressure in the meter . There is a small valve on the lower Pitot tube connection , which when closed prevents the condensed steam from flowing out .

Method of operation.

The steam valve "C",(see blue print No. 1) was first opened admiting steam from the main steam header . The steam passes thru the separator and then down a 2 inch pipe, at the bottom of which is placed a drain "G". After this part of the piping had become throughly warm , the globe valve "A" was cracked open , and the drains "E" and "F" , were opened . After this part of the piping had also become throughly warm , the valve "B" was opened which allowed steam to flow to the condenser . The steam was allowed to flow thru at a low rate for a few minutes , after which the

valve "B" was closed , and the pressure in the pipe to which the meter was connected was brought to the required pressure by the manipulation of the valve "A" , and the zero reading of the meter was found . To be sure that there was enough condensed steam in the meter , the little valve on the lower Pitot tube , mentioned above , was closed . Then when the pointer indicated that the head of water in the meter had increased considerably , this small valve was opened which allowed the condensed steam to run out , thus bringing the indicator back to the true zero point . At the same time the height of the water in the gage glass was noted as the zero reading of the velocity head . After obtaining the zero readings of both instruments , the valve " C" was opened wide , and the valve "B" opened to a point which gave approximately the flow required as shown by the meter reading . The pressure was maintained constant by means of the valve "A" . After allowing conditions to become constant, the condensed steam was turned into a tank and the

amount of steam passing by the meter in a certain period of time was found . The length of these periods varied from 20 to 60 minutes, depending , upon the time the pressure could be maintained , and upon the velocity of the steam thru the pipe. The length of various runs may be readily seen from the running logs. The following readings were taken every ten minutes; the weight of the weighing tanks; the reading of the meter; and the velocity head as recorded by the gage glass in inches of water.

Theory:

The calculation of the theoretical velocity head in inches of water, by means of the formula $v = \sqrt{2gh}$. *

Let v = velocity in feet per second.

h = velocity head in inches of water.

H = velocity head in feet of steam.

d_1= weight of a cubic foot of water at a temperature "t", corresponding to a pressure "p".

d_2= weight of a cubic foot of steam at a known pressure "p".

A = area pf pipe in square feet.

V = volume of steam discharged, in cu.ft. per hour.

w = weight of steam discharged, in lbs. per hour.

Then the pressure per sq.in. of one inch of water

$$= \frac{d_1}{1728}$$

---

* Refer to W. M. White.

"The Pitot Tube, and Its Formula."

Jor. of the Assosiation of the Eng.Soc. Vol.27,p 35.

and the pressure per sq. in. of one cubic foot of steam

$$= \frac{d_2}{144} ,$$

Then

$$H = h \frac{d_1}{12d_2} ,$$

$$v = \sqrt{2gH} = \sqrt{2gh \frac{d_1}{12d_2}} .$$

$$V = 3600vA .$$

$$= 3600 A \sqrt{\frac{ghd_1}{6d_2}} .$$

also $$w = Vd_2 = 3600 A \sqrt{\frac{ghd_1d_2}{6}}$$

$$w = 8341 A \sqrt{hd_1d_2}$$

This is a general formula for any size pipe , and for any pressure.

For a 3 inch pipe this formula reduces to

$$w = 425\sqrt{hd_1d_2}$$

where A = .05047 sq.ft.

For a 4 inch pipe this formula reduces to

$$w = 738\sqrt{hd_1d_2}$$

where A = .0886 sq.ft.

By substituting the proper values of d_1 and d_2, we obtain the following formulas from which the theoretical curves shown were plotted.

For a 3 inch pipe:

At a pressure of 70 lbs. gage,

$$w = 1410\sqrt{h}\ .$$

At a pressure of 80 lbs. gage,

$$w = 1482\sqrt{h}\ .$$

At a pressure of 90 lbs. gage,

$$w = 1552\sqrt{h}\ .$$

For a 4 inch pipe:

At a pressure of 70 lbs. gage,

$$w = 2450\sqrt{h}\ .$$

At a pressure of 80 lbs. gage,

$$w = 2575\sqrt{h}\ .$$

At a pressure of 90 lbs. gage,

$$w = 2695\sqrt{h}\ .$$

RUNNING LOG

Diam. of pipe 3.06in. Date. May, 5th.1902.

Area of pipe .05047sq.ft. Bar.in.Hg. = 29.45

0 reading of meter 73. 0 of Vel.head = 0.

TIME	Meter Reading	Wt. of steam used		Vel.head in " H_2O	Steam press. cor.
		Full	Net		
		RUN	# 1.	.68	
1:05	156	546.5	0	.60	70
1:15	155	755	208.5	.55	70
1:25	157	965	210	.60	70
Average	156	1173	208	.60	70
Average	156		208.8	.59	70
	Steam used per hour = 1253 lbs.				

RUNNING LOG

Diam. of pipe 3.05in. Date. May,6th.190[illegible].

Area of pipe .05047sq.ft. Bar.in.Hg. = 29.35

0 reading of meter 0 reading of vel.h.0.

TIME	Meter Reading	Wt of steam used		Vel.head in " H_2O	Steam press. cor.
		Full	Net		
		RUN # 1.			
2:30	233	582	0	.45	70
2:40	233	760	178	.38	70
2:50	233	933	173	.38	70
3:00	232	1111	178	.40	70
Average	233		176.33	.387	70
Steam used per hour =			1058 lbs.		
		RUN # 2.			
3:10	206	568	0	.20	70
3:20	207	711	143	.20	70
3:30	207	880	169	.20	70
3:40	206	994	114	.20	70
Average	206.5		142	.20	70
Steam used per hour =			852 lbs.		

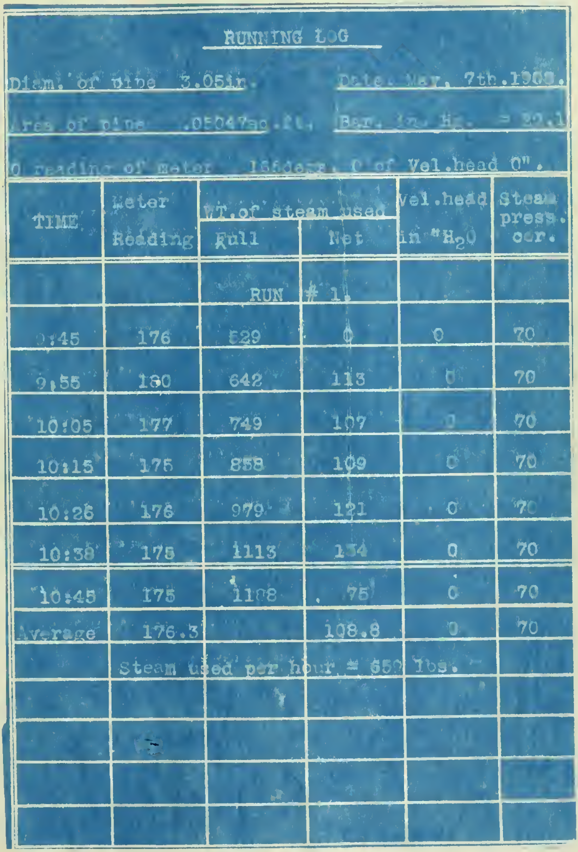
RUNNING LAD

Diam. of pipe 3.058in.   Date, May, 6th.1909

Area of pipe .05047sq.ft.   Bar.in.Hg. =29.55

0 reading of meter   0 reading of Vel.h.0

TIME	Meter Reading	Wt.of steam used		Vel.head in" H_2O	Steam prems. cor.
		Full	Net		
		RUN # 3.			
4:00	218	618	0	.25	70
4:10	219	784.5	166.5	.25	70
4:20	218	944	159.5	.25	70
4:30	218	1093	149.0	.22	70
Average	218		158.33	.243	70
	Steam used per hour = 950 lbs.				
		RUN # 4.			
4:49	285	530	0	.60	70
5:00.5	285	783.5	253.5	.60	70
5:10	285	1000	216.5	.60	70
5:19	285	1202.5	202.5	.60	70
Average	285		224.5	.60	70
	Steam used per hour = 1345.0 lbs.				



RUNNING LOG

Diam. of pipe 3.05in. Date: May, 7th.1908.

Area of pipe .05047sq.ft. Bar. in. Hg. = 29.1

0 reading of meter 156degs. 0 of Vel.head 0".

TIME	Meter Reading	WT.of steam used		Vel.head in "H_2O	Steam press. cor.
		Full	Net		
		RUN	# 1.		
9:45	176	529	0	0	70
9:55	180	642	113	0	70
10:05	177	749	107	0	70
10:15	175	858	109	0	70
10:26	176	979	121	0	70
10:38	175	1113	134	0	70
10:45	175	1188	75	0	70
Average	176.3		108.8	0	70
	Steam used per hour = 653 lbs.				

RUNNING LOG

Diam. of pipe 3.05in. Date. May, 7th. 1908.

Area of pipe .05047sq.ft. Bar. In. Hg. =29.1

0 reading of meter 165 degs. 0 of Vel. head 0 in.

TIME	Meter Reading	WT. of steam used		Vel. head in "H_2O	Steam press. cor.
		Full	Net		
		RUN	# 2.		
11:20	415	546.5	0	1.15	70
11:30	403	859	312.5	1.15	70
11:40	403	1179	320	1.15	70
11:50	425	1490	311	1.15	70
Average	413		314.5	1.15	70
	Steam used per hour = 1887 #bs.				
		RUN	# 3.		
12:01	321	536.5	0	.78	70
12:11	310	795	258.5	.78	70
12:21	318	1048	253	.76	70
12:31	3[illegible]1	1305	257	.75	70
Average	319.7		256.2	.77	70
	Steam used per hour = 1537 lbs.				

RUNNING LOG

Diam. of pipe 3.05in. Date. May, 7th.1908.

Area of pipe .05047sq.ft. Bar. in. Hg. = 29.1

0 reading of meter 165 degs. 0 of Vel.head= 0"

TIME	Meter Reading	Wt.of steam used		Vol.head in "H_2O	Steam press. cor.
		Full.	Net		
		RUN	# 4.		
1:38	190	536	0	.15	80
1:48	195	665	129	.15	80
1:58	195	799	134	.20	80
2:08	195	933	134	.15	80
Average	193.8		132.3	.163	80
	Steam	used per	hour = 794 lbs.		
		RUN	# 5.		
3:11	222	540	0	.40	80
3:21	222	720	180	.40	80
3:31	218	895	175	.35	80
3:41	220	1070	175	.30	80
Average	221		177	.363	80
	Steam	used per	hour =	1060 lbs.	

RUNNING LOG

Diam. of pipe 3.05 in. Date. May 7th. 1908.

Area pf pipe .05047 sq.ft. Bar. in. Hg. = 29.1

0 reading of meter 172 0 of vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vel.head in " H_2O	Steam press. corr.
		Full	Net		
3:55	273	538	0	.60	80
4:00	275	6565	118	.57	80
4:10	275	885	229	.63	80
4:20	275	1119	234	.63	80
Average	274.5		233	.908	80
	Steam used per hour =			1538 lbs.	
	Difference in meter reading = 102.5 deg.				

[illegible]
INSTITUTE OF TECHNOLOGY
LIBRARY.

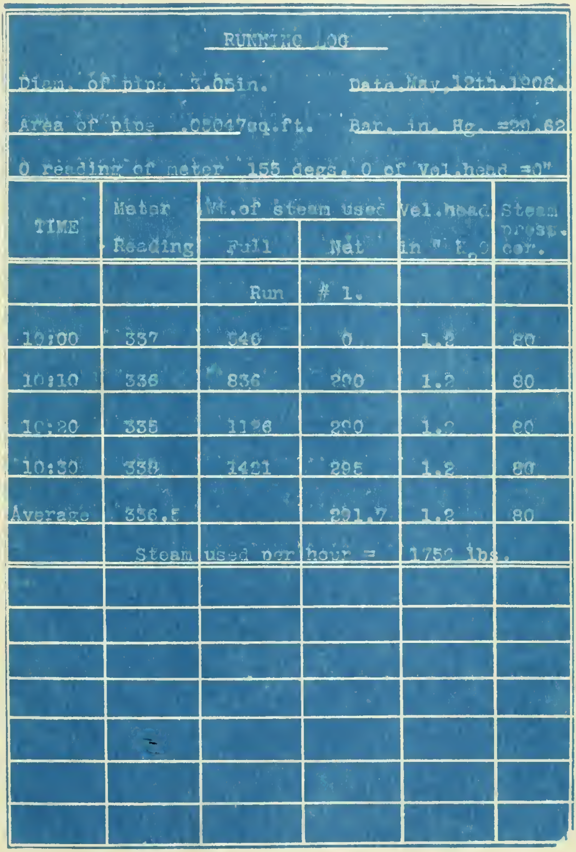
RUNNING LOG

Diam. of pipe 3.05in. Date. May, 8th 1908.

Area of pipe .05047sq.ft. Bar. in. Hg. =

0 reading of meter 170 degs. 0 of Vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vol.head in "H_2O	Steam press cor.
		Full	Net		
		RUN	# 1.		
10:00	247	530	0	.57	80
10:10	248	740	210	.56	80
10:20	246	950	210	.59	80
10:30	245	1157.5	207.3	.61	80
Average	246.5		209.1	.58	80
	Steam used per hour =			1255 lbs.	



RUNNING LOG

Diam. of pipe 3.05in. Data May,12th.1908.

Area of pipe .05047sq.ft. Bar. in. Hg. =29.62

0 reading of meter 155 degs. 0 of Vel.head =0"

TIME	Meter Reading	Wt.of steam used		Vel.head in " H_2O	Steam press. cor.
		Full	Net		
		Run	# 1.		
10:00	337	546	0	1.2	80
10:10	336	836	290	1.2	80
10:20	335	1126	290	1.2	80
10:30	338	1421	295	1.2	80
Average	336.5		291.7	1.2	80
	Steam	used per	hour =	1750 lbs.	

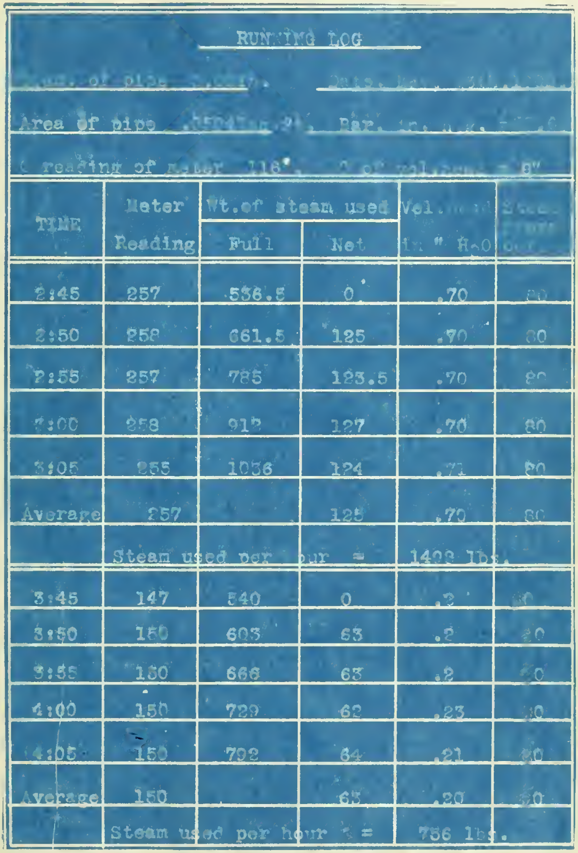
RUNNING LOG

Diam. of pipe 3.05in. Date. May, 13th.1908

Area of pipe .05047sq.ft. Bar. in. Hg.= 29.42

0 reading of meter 116 degs. 0 of vel.head = 0

TIME	Meter Reading	Wt.of steam used		Vel head in "H_2O	Steam press cor.
		Full	Net		
1:45	393	546	0	1.32	80
1:50	395	710	164	1.30	80
1:55	395	880	170	1.30	80
2:00	396	1048	168	1.40	80
2:05	392	1218	164	1.40	80
Average	394		166.5	1.34	80
	Steam used per hour =			2016 lbs.	
2:15	330	535	0	1.10	80
2:20	330	688	153	1.05	80
2:25	329	838	150	1.02	80
2:30	330	980	152	1.06	80
2:35	332	1140	160	1.02	80
Average	330		153	1.05	80
	Steam used per hour =			1815 lbs.	



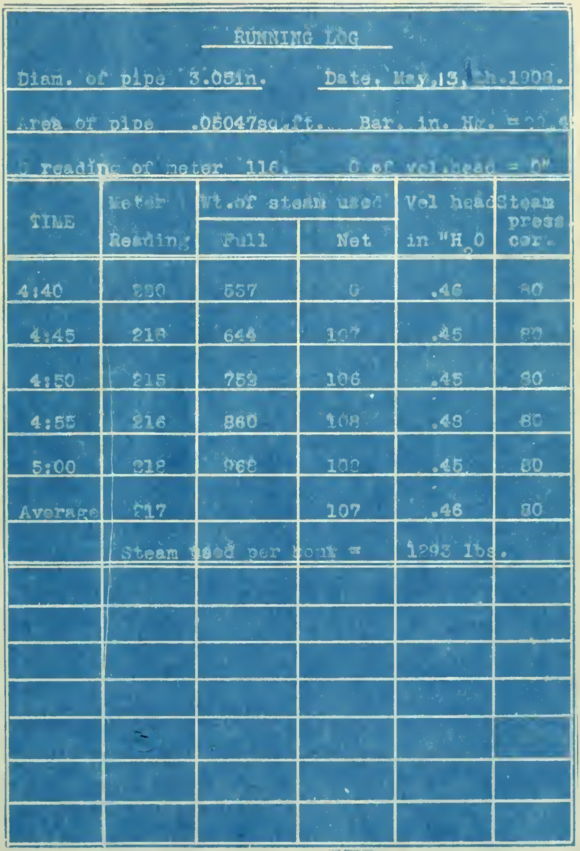
RUNNING LOG

[illegible] of pipe [illegible] Date, [illegible]

Area of pipe [illegible] Bar. in. [illegible]

[illegible] reading of meter 116". [illegible] of vel. [illegible] = 8"

TIME	Meter Reading	Wt. of steam used		Vel. head in " H_2O	Steam Press. [illegible]
		Full	Net		
2:45	257	536.5	0	.70	80
2:50	258	661.5	125	.70	80
2:55	257	785	123.5	.70	80
3:00	258	912	127	.70	80
3:05	255	1036	124	.71	80
Average	257		125	.70	80
	Steam used per hour =			1498 lbs.	
3:45	147	540	0	.2	80
3:50	150	603	63	.2	80
3:55	150	666	63	.2	80
4:00	150	729	62	.23	80
4:05	150	792	64	.21	80
Average	150		63	.20	80
	Steam used per hour =			756 lbs.	



RUNNING LOG

Diam. of pipe 3.051n. Date. May 13th. 1908.

Area of pipe .05047sq.ft. Bar. in. Hg. = [illegible]

0 reading of meter 116. 0 of vel. head = 0"

TIME	Meter Reading	Wt. of steam used		Vel head in "H_2O	Steam press cor.
		Full	Net		
4:40	220	537	0	.46	80
4:45	218	644	107	.45	80
4:50	215	753	106	.45	80
4:55	216	860	108	.48	80
5:00	218	968	108	.45	80
Average	217		107	.46	80
	Steam used per hour =			1293 lbs.	

RUNNING LOG

Diam. of pipe 3.06 in. Date: Mar. 14th, 190[illegible]

Area of pipe .0[illegible] sq.ft. Bar. in. Hg. = [illegible]

0 reading of meter 115. 0 of vel.head = [illegible]

TIME	Meter Reading	Wt. of steam used		Vel. head in " H_2O.	Steam press cor.
		Full	Net		
10:45	172	526.5	0	.2	80
10:55	175	682.5	156	.22	80
11:05	173	836.5	154	.21	80
11:15	172	995	158.5	.21	80
Average	172		156.2	.21	80
	Steam used per hour =			937 lbs.	
11:30	148	543.5	0	.20	80
11:40	146	666.5	123	.17	80
11:50	150	787.4	121	.15	80
12:00	148	911.	124.5	.12	80
Average	148		122.8	.16	80
	Steam used per hour =			735 lbs.	

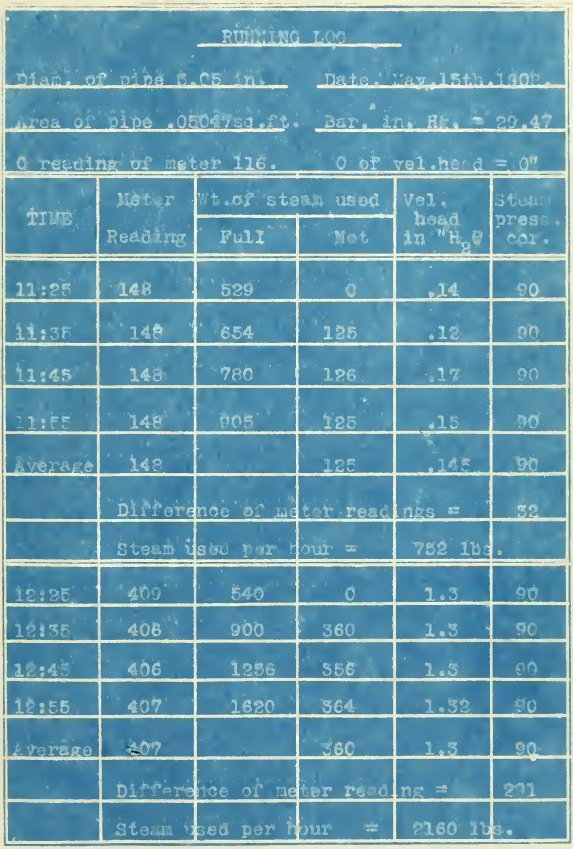
RUNNING LOG

Diam. of pipe 3.05in. Date. May 14, '08

Area of pipe .05047sq. ft. Bar. in. Hg. =29.4

0 reading of meter 115. 0 of vel. head = 0"

TIME	Meter Reading	Wt. of steam used		Vel. head in " H_2O.	Steam press. $^{\circ}$F.
		Full	Net		
12:10	132	541	0	.11	80
12:20	131	626	85	.09	80
12:30	130	709	83	.08	80
12:40	130	791	82	.09	80
Average	131		83.3	.09	80
	Steam used per hour =			500 lbs.	



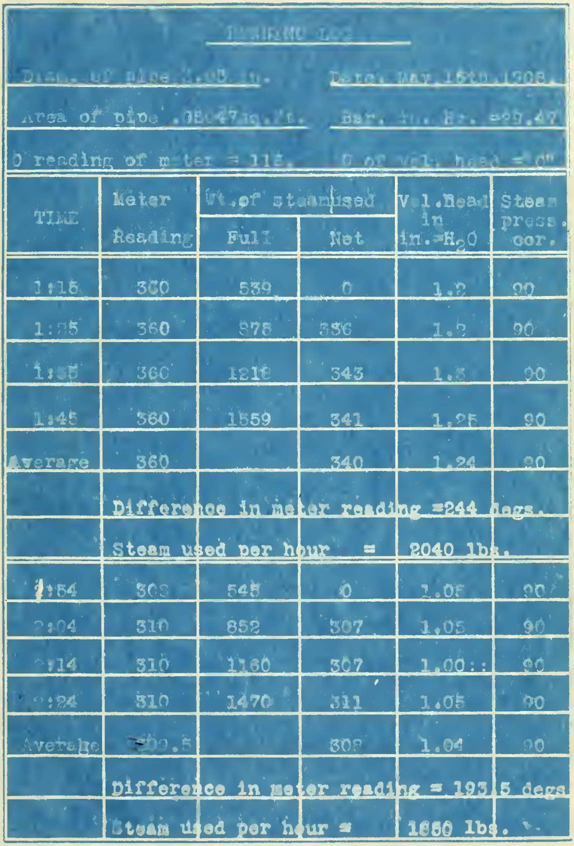
RUNNING LOG

Diam. of pipe 3.05 in. Date. May 15th 1908.

Area of pipe .05047sq.ft. Bar. in. Hg. = 29.47

0 reading of meter 116. 0 of vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vel. head in "H_2O	Steam press. cor.
		Full	Net		
11:25	148	529	0	.14	90
11:35	148	654	125	.12	90
11:45	148	780	126	.17	90
11:55	148	905	125	.15	90
Average	148		125	.145	90
	Difference of meter readings =				32
	Steam used per hour =			752 lbs.	
12:25	409	540	0	1.3	90
12:35	406	900	360	1.3	90
12:45	406	1256	356	1.3	90
12:55	407	1620	364	1.32	90
Average	407		360	1.3	90
	Difference of meter reading =				291
	Steam used per hour =			2160 lbs.	



RUNNING LOG

Diam. of pipe [illegible] in. Date, May 16th 1908.

Area of pipe .05047 sq.ft. Bar. in. Hg. =29.47

0 reading of meter = 118. 0 of vel. head = 0"

TIME	Meter Reading	Wt. of steam used		Vel. Head in in. H_2O	Steam press. cor.
		Full	Net		
1:15	360	539	0	1.2	90
1:25	360	878	336	1.2	90
1:35	360	1218	343	1.3	90
1:45	360	1559	341	1.25	90
Average	360		340	1.24	90
	Difference in meter reading =244 degs.				
	Steam used per hour =			2040 lbs.	
1:54	309	545	0	1.05	90
2:04	310	852	307	1.05	90
2:14	310	1160	307	1.00	90
2:24	310	1470	311	1.05	90
Average	309.5		308	1.04	90
	Difference in meter reading = 193.5 degs.				
	Steam used per hour =			1850 lbs.	

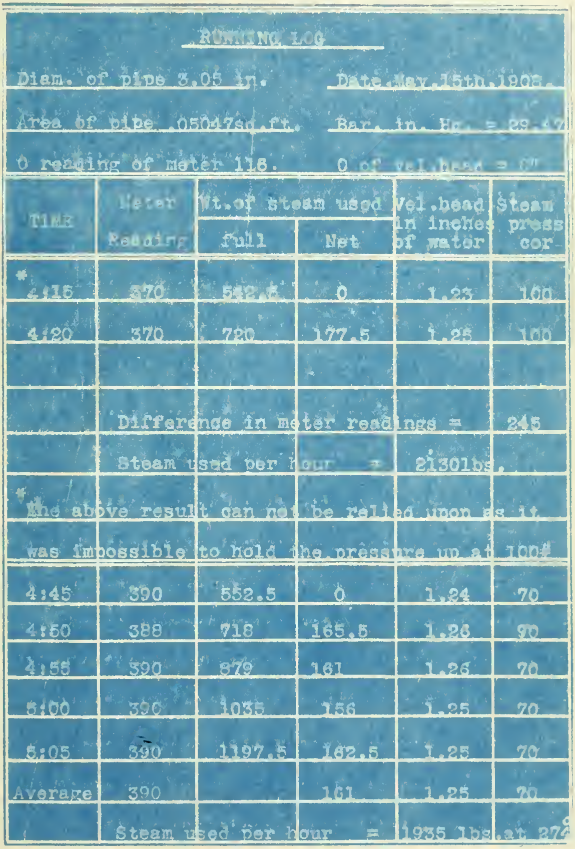
RUNNING LOG

Dia. of pipe 3.05 in. Date. May.15th.190

Area of pipe .05047sq.ft. Bar. in. Hg. =29.4

0 reading of meter 116. 0 of vel.head = 0"

TIME	Meter Reading	Wt. of steam used		Vel.head in in. H2O.	Steam press. cor.
		Full	Net		
2:31	257	543	0	0.7	90
2:41	260	813	270	0.78	90
2:51	238	1087	274	0.75	90
3:01	278	1357	270	0.8	90
Average	258		271	0.76	90
	Difference in meter readings =				142
	Steam used per hour =			1088 lbs.	
3:11	180	545.5	0	.44	90
3:21	179	737	191.5	.43	90
3:31	187	930	193	.41	90
3:41	181	1117	187	.40	90
Average	180		190.5	.42	90
	Difference in meter readings =				64
	Steam used per hour =			1143 lbs.	



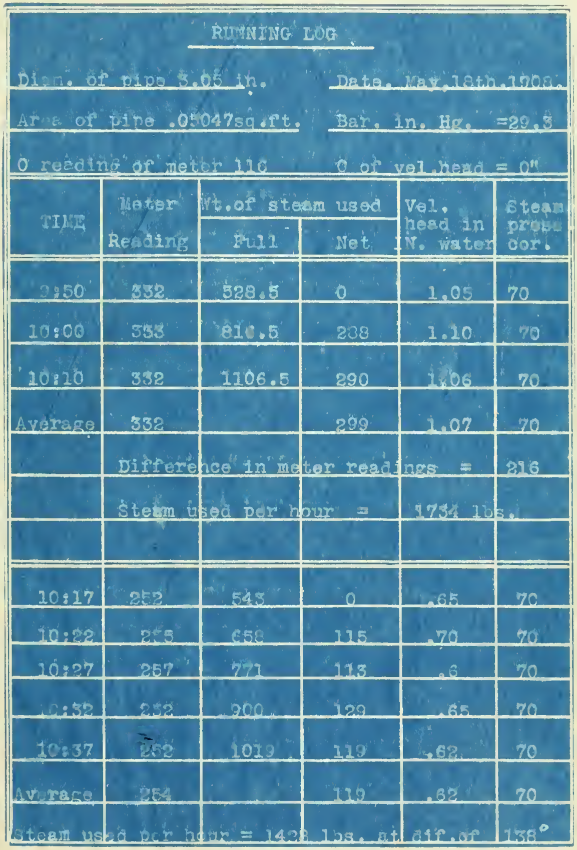
RUNNING LOG

Diam. of pipe 3.05 in. Date.May.15th.1908.

Area of pipe .05047sq.ft. Bar. in. Hg. = 29.47

0 reading of meter 116. 0 of vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vel.head in inches of water	Steam press cor
		full	Net		
* 4:15	370	552.5	0	1.23	100
4:20	370	720	177.5	1.25	100
	Difference in meter readings =				245
	Steam used per hour =			2130lbs.	
* The above result can not be relied upon as it					
was impossible to hold the pressure up at 100#					
4:45	390	552.5	0	1.24	70
4:50	388	718	165.5	1.26	90
4:55	390	879	161	1.26	70
5:00	390	1035	156	1.25	70
5:05	390	1197.5	162.5	1.25	70
Average	390		161	1.25	70
	Steam used per hour =			1935 lbs.at 274°	



RUNNING LOG

Diam. of pipe 3.05 in. Date. May 18th.1908.

Area of pipe .05047sq.ft. Bar. in. Hg. =29.3

0 reading of meter 116 0 of vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vel. head in IN. water	Steam press cor.
		Full	Net		
9:50	332	528.5	0	1.05	70
10:00	333	816.5	238	1.10	70
10:10	332	1106.5	290	1.06	70
Average	332		299	1.07	70
	Difference in meter readings =				216
	Steam used per hour =			1734 lbs.	
10:17	252	543	0	.65	70
10:22	255	658	115	.70	70
10:27	257	771	113	.6	70
10:32	252	900	129	.65	70
10:37	252	1019	119	.62	70
Average	254		119	.62	70
Steam used per hour = 1428 lbs. at dif.of					138°

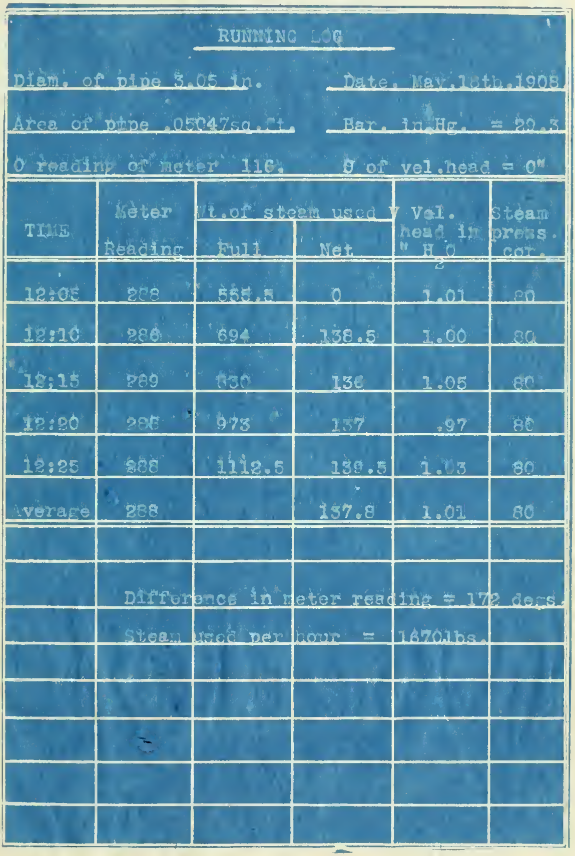
RUNNING LOG

Diam.of pipe 3.05 in. Date . May 13th, 1908

Area of pipe .05047sq.ft. Bar. in. Hg. = [illegible]

0 reading of meter 116. 0 of vel. head = 0"

TIME	Meter Reading	Wt.of steam used		Vel. head in " H_2O	Steam press. cor.
		Full	Net		
10:45	185	534.5	0	.25	70
10:50	185	619.5	84.5	.22	70
10:55	185	705	85.5	.20	70
11:00	184	790	85	.20	70
11:05	184	876	86	.23	70
Average	185		85	.22	70
Steam used per hour = 1024 lbs. at dif. of 69°					
11:25	146	537.5	0	.12	70
11:35	144	654.5	117	.12	70
11:45	144	769	114.5	.10	70
11:55	144	884	115	.12	70
Average	144		115	.115	70
	Difference in meter readings =				28°
	Steam used per hour =			693 lbs.	



RUNNING LOG

Diam. of pipe 3.05 in.

Date. May.18th.1908

Area of pipe .05047sq.ft.

Bar. in.Hg. = 29.3

0 reading of meter 116.

0 of vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vel. head in " H_2O	Steam press. cor.
		Full	Net		
12:05	288	555.5	0	1.01	80
12:10	288	694	138.5	1.00	80
12:15	289	830	136	1.05	80
12:20	286	973	137	.97	80
12:25	288	1112.5	139.5	1.03	80
Average	288		137.8	1.01	80

Difference in meter reading = 172 degs.

Steam used per hour = 1670lbs.

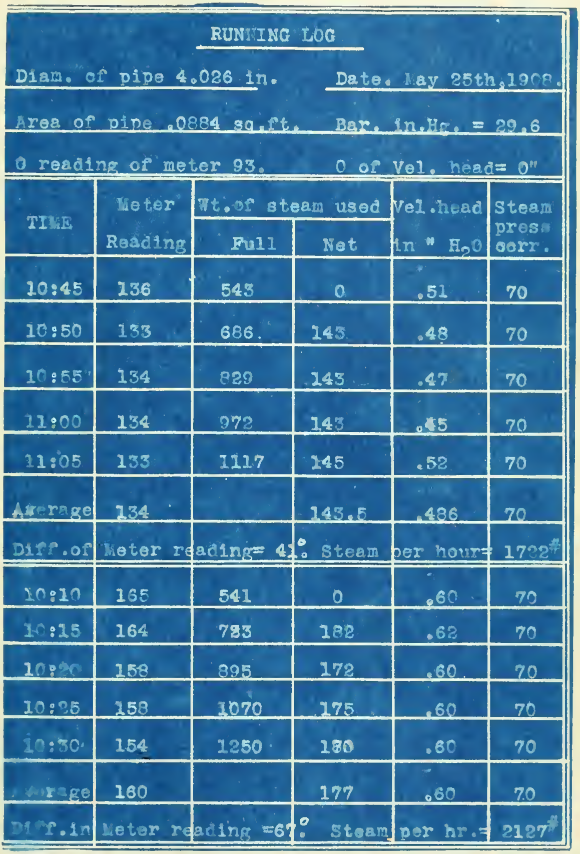
RUNNING LOG

Diam. of Pipe 4.026 in. Date. May25th, 1908.

Area of Pipe .0884 sq.ft. Bar. in. Hg. 29.6

0 reading of meter 93. 0 of Vel. head = 0"

TIME	Meter Reading	Wt.of steam used		Vel.head in "H_2O	Steam press corr.
		Full	Net		
9:49	104	554	0	.4	70
9:54	105	640	86	.40	70
9:59	103	719	79	.40	70
10:04	103	799	80	.30	70
10:09	101	881	82	.35	70
Average	103		81.8	.37	70
Diff. of Meter reading= 10°			Steam per hr.=981#		
10:15	117	541	0	.42	70
10:20	112	652	111	.45	70
10:25	113	763	111	.40	70
10:30	115	874	111	.44	70
10:35	113	984.5	110.5	.40	70
Average	114		111	.42	70
Diff. in Meter reading=21			Steam per hr. =1330#		



RUNNING LOG

Diam. of pipe 4.026 in.

Date. May 25th, 1908.

Area of pipe .0884 sq.ft.

Bar. in.Hg. = 29.6

0 reading of meter 93.

0 of Vel. head= 0"

TIME	Meter Reading	Wt. of steam used		Vel. head in " H_2O	Steam press corr.
		Full	Net		
10:45	136	543	0	.51	70
10:50	133	686	143	.48	70
10:55	134	829	143	.47	70
11:00	134	972	143	.45	70
11:05	133	1117	145	.52	70
Average	134		143.5	.486	70
Diff.of Meter reading= 41°. Steam per hour= 1722#					
10:10	165	541	0	.60	70
10:15	164	723	182	.62	70
10:20	158	895	172	.60	70
10:25	158	1070	175	.60	70
10:30	154	1250	180	.60	70
Average	160		177	.60	70
Diff.in Meter reading =67°. Steam per hr.= 2127#					

RUNNING LOG

Diam. of pipe 4.026 in. Date, May 25th, 1908.

Area of pipe .0884sq.ft. Bar. in. Hg. = 29.6

P reading of meter 93. 0 of Vel.head = 0"

TIME	Meter Reading	Wt.of steam used		Vel.head in " H_2O	Steam press corr.
		Full	Net		
11:35	185	539	0	.90	70
11:40	185	758	219	.89	70
11:45	185	976	218	.82	70
11:50	185	1196	220	.95	70
11:55	185	1418	222	.92	70
Average	185		219.8	.896	70
Diff.in	Meter reading= 92°.		Steam	per hr.=	2637#
12:00	193	540	0	1.12	70
12:05	198	770	230	1.1	70
12:10	195	1005	235	1.05	70
Average	195		232.5	1.09	70
Difference in	Meter reading =			102 degs.	
Steam used per hour =			2790 lbs.		

LOG FORM

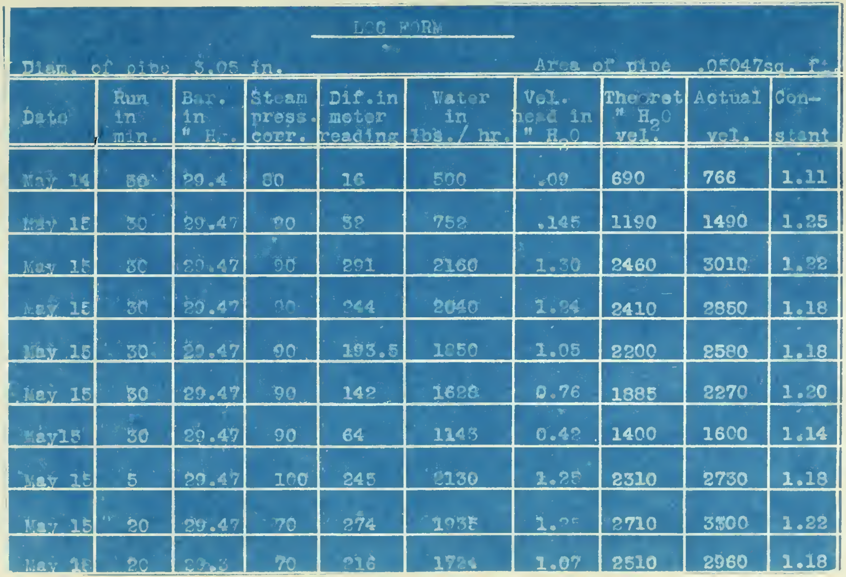
Diam. of pipe 3.05in. Area of pipe .05047sq.ft.

Date	Run in mins.	Bar. in " Hg.	Steam press corr	Dif. in meter reading	Water in lbs./ hr.	Vel.head in " H_2O	Theoret vel.in ft/min	Actual vel on ft/min	Constant
May 5	30	29.45	70	83	1253	.590	1960	2137	1.09
May 6	30	29.35	70	55	1058	.387	1462	1800	1.28
May 6	30	29.35	70	28	852	0.20	1072	1450	1.25
May 6	30	29.35	70	40	950	.243	1365	1620	1.19
May 6	30	29.35	70	107	1345	.600	1860	2290	1.23
May 7	60	29.1	70	11.3	659	.00	0	1120	
May 7	30	29.1	70	248	1887	1.15	2585	3210	1.24
May 7	30	29.1	70	154.7	1537	.770	2110	2610	1.24
May 7	30	29.1	80	28.8	784	.163	903	1215	1.04
May 7	30	29.1	80	56	1060	.363	1360	1620	1.19

[illegible]

Diam. of pipe 3.05 in. [illegible]

Date	Run in min.	Bar. in " Hg.	Steam press. cor.	Dif. in Meter reading	Water in lbs./hr.	Vel. head in " H_2O	Theoret vel in ft/min	Act-ual vel.	Con-stant
May 7	25	29.1	80	102.5	1538	.608	1765	2360	1.34
May 8	30	29.5	80	76.5	1255	.580	1735	1925	1.11
May [illegible]	30	29.62	80	181.5	1750	1.20	2500	2680	1.07
May 13	20	29.42	80	278	2016	1.34	2640	3090	1.17
May 13	20	29.42	80	214	1815	1.05	2340	2780	1.19
May 13	20	29.42	80	141	1498	.70	1900	2290	1.20
May 13	20	29.42	70	34	756	.20	1075	1290	1.20
May 13	20	29.42	80	101	1293	.46	1550	1980	1.28
May 14	30	29.4	80	57	937	.21	1055	1435	1.36
May 14	30	29.4	80	33	735	.16	905	1125	1.25



LOG FORM

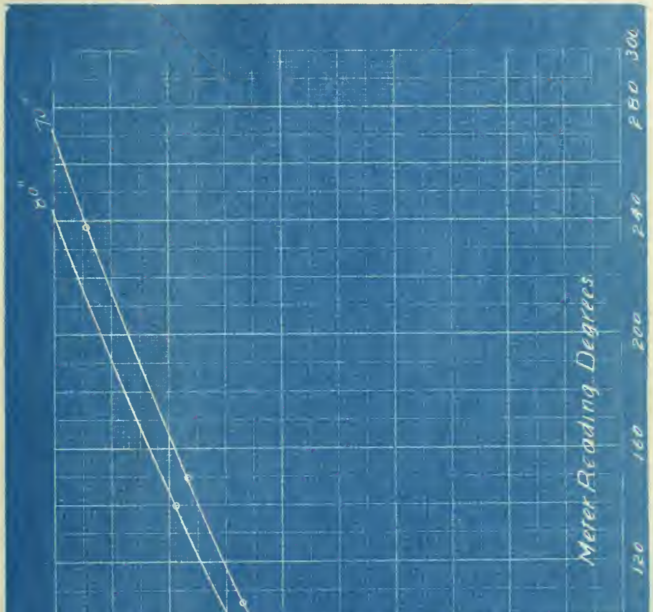
Diam. of pipe 3.05 in. Area of pipe .05047sq. ft.

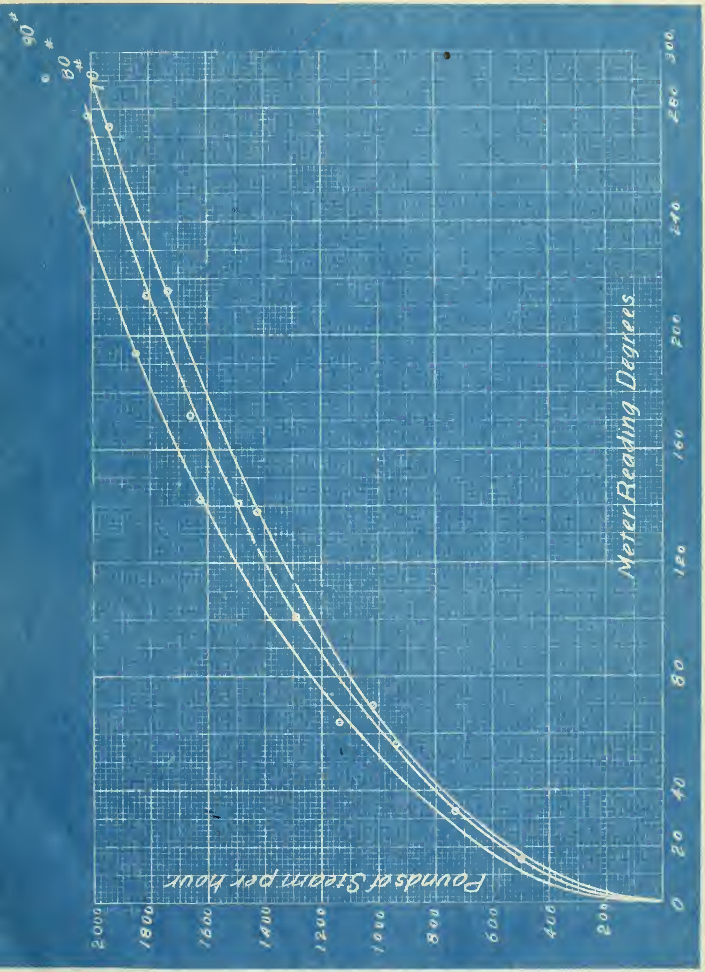
Date	Run in min.	Bar. in " Hg.	Steam press. corr.	Dif. in meter reading	Water in lbs./ hr.	Vel. head in " H_2O	Theoret " H_2O vel.	Actual vel.	Constant
May 14	30	29.4	80	16	500	.09	690	766	1.11
May 15	30	29.47	90	52	752	.145	1190	1490	1.25
May 15	30	29.47	90	291	2160	1.30	2460	3010	1.22
May 15	30	29.47	90	244	2040	1.24	2410	2850	1.18
May 15	30	29.47	90	193.5	1850	1.05	2200	2580	1.18
May 15	30	29.47	90	142	1628	0.76	1885	2270	1.20
May15	30	29.47	90	64	1143	0.42	1400	1600	1.14
May 15	5	29.47	100	245	2130	1.25	2310	2730	1.18
May 15	20	29.47	70	274	1935	1.[illegible]	2710	3300	1.22
May 16	20	29.3	70	216	1724	1.07	2510	2960	1.18

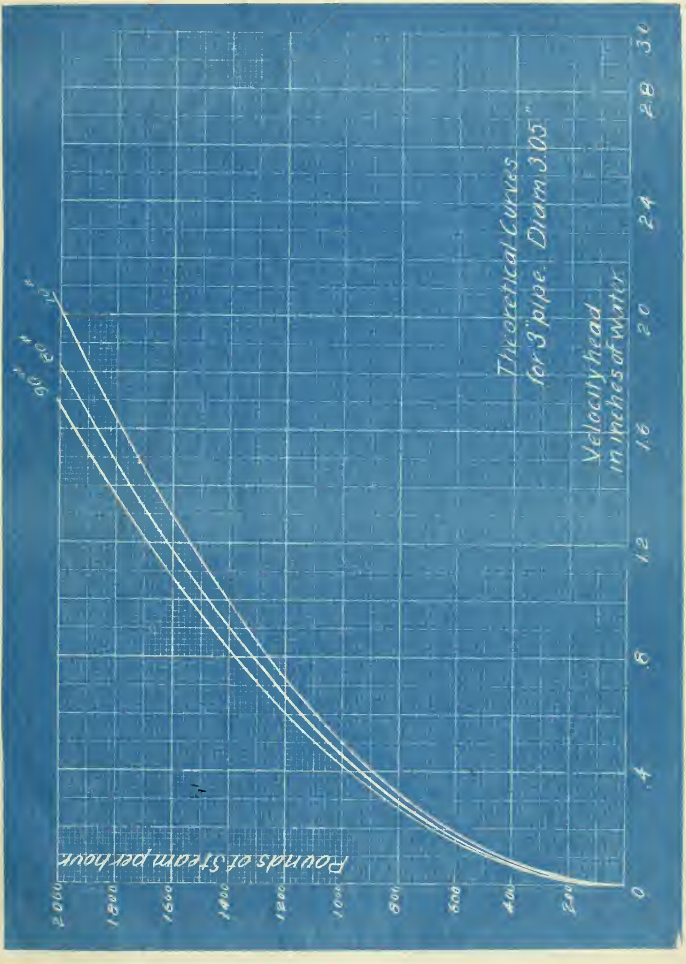
LOG FORM

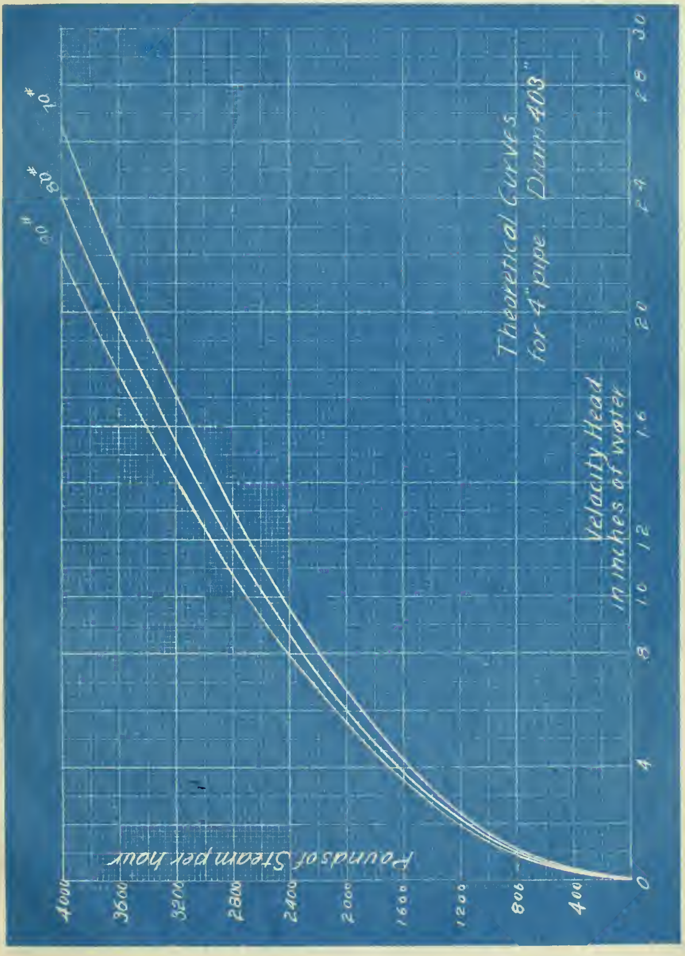
Diam. of pipe 3.05 in. Area of pipe .05047sq.ft.

Date	Run in mins.	Bar. in " Hg.	Steam press corr.	Dif. in meter reading	Water in lbs./ hr.	Vel. head in " H_2O	Theoret vel. " H_2O	Actual vel.	Con-stant
May 18	20	29.3	70	138	1428	.62	1890	2430	1.28
May 18	20	29.3	70	69	1024	.22	1140	1750	1.53
May 18	20	29.3	70	28	693	.115	766	1180	1.54
May 18	20	29.3	70	172	1670	1.01	2420	2840	1.17


Meter Reading Degrees
Pounds of Steam per hour
0
20
40
80
120
160
200
240
280
300
200
400
600
800
1000
1200
1400
1600
1800
2000
70
80"


90#
80#
70#
Meter Reading Degrees
Pounds of Steam per hour
0
20
40
80
120
160
200
240
280
300
200
400
600
800
1000
1200
1400
1600
1800
2000


Theoretical Curves
for 3" pipe. Diam 3.05"
Velocity head
in inches of Water
Pounds of Steam per hour
90#
80#
10#
0
4
8
12
16
20
24
28
30
200
400
600
800
1000
1200
1400
1600
1800
2000


Theoretical Curves
for 4" pipe   Diam 403"
60#
80#
10#
Pounds of Steam per hour
4000
3600
3200
2800
2400
2000
1600
1200
800
400
Velocity Head
in inches of water
0
4
8
1.0
12
1.6
20
24
28
30

Calibration of steam gage # 603 R 784.

True Pressure in lbs.per sq.in.	Gage Readings, going UP	DOWN
50	54.5	54.5
60	64.5	64.5
70	75.0	75.0
80	84.5	84.5
90	94.5	94.5
100	104.5	104.5
110	114.5	114.5
120	124.5	124.5

Discussion.

The data obtained May 5 to May 12 with the form of the Pitot tube as shown by Fig. 1 , plot very nicely, as may be seen from curves on page 42. The data obtained May 12th to May 23rd with the form of the Pitot tube as shown by Fig.3 , also follows a definite curve. (See page 43.)

The greatest difficulty, was found in obtaining the zero reading of the meter. With the form of tube shown in Fig.1 , and with no flow of steam thru the pipe, a small ball of water seems to form on top of the Pitot tube due to surface tension. If the tube was jarred, the small ball of water would break and cause an error in the zero reading of the meter. The small capillary tube with the copper wick, mentioned above, was inserted to overcome this difficulty, and seems to have succeeded in preventing the formation of the ball of water, as it lowered the zero reading of the meter from 10 to 20 degrees.

As may be seen from the log forms, the constant of the gage glass is approximatly 1.20. This con -

stant, we believe, should be very nearly unity.This different may have been caused either, by the error due to the fluctuation of the velocity head, which error is very large at low velocities, or that the zero point of the gage glass may have been wrong. This error of the zero point, due to the small ball of water which forms on top of the Pitot tube, may amount to 0.20 of an inch when there is no flow of steam thru the pipe.

Runs were made on a 4 inch pipe, but the results were unsatisfactory. This was found to be due to the bending of the connecting rod in the meter. This and many similar accidents hindered us from obtaining more complete data.

Conclusions.

1. That there is a well defined curve showing the relation between the meter readings and the flow of steam thru the pipe per hour.

2. That the curves are of the same form for different pressures, and hold the same relation to each other as do the theoretical curves.

3. That the curves obtained with the second form of Pitot tube as shown by Fig. 3 , follow more nearly the slope of the theoretical curves than those obtained with the form of Pitot tube as shown by Fig. 1 , which is undoubtedly due to the small capillary tube.

4. That within the limit below which we ran, namely 2 inches of water, the gage glass instrument does not give good results.

5. That the meter is of good pratical use where the steam passing it, is dry and saturated , and where the steam pressure is constant.

6. That a disadvantage of the meter is, that there must be a different calibration for every pressure.

C. F. Busse
L. C. Friedlander.

BIBLIOGRAPHY.

Prof. G. F. Gebhardt.

"Formulas for the Flow of Steam in Pipes."

Power,1907. Vol.27. Page 377.

W.B.Gegory.

" The Pitot Tube."

A. S. M. E. Vol. 25, page 184.

W. M. White.

" The Pitot Tube; Its Formula."

Jor. of the Assoisiation of the Eng. Soc.

Vol. 27, 1901.

W. M. White.

" A New Method of Reducing the Readings of the Pitot Tube."

American Machinist. Vol. 29², page 175.

R. C. Carpenter.

"Experiments of the Flow of Steam Thru Pipes."

A. S. M. E. Vol.14, page 751.

R. Burnham.

" The Pitot Tube."

Eng. News, Dec. 21, 1905.

BIBLIOGRAPHY.

R. Threlfall.

"The Motion of Gases in Pipes and the use of gages to Determine the Delivery."

Pro. of the Inst. of Mech. Engs. 1904,page245.

R. Threlfall.

"The Testing of Electric Generators by Air Calorimetry."

Jor. Inst. of Elec. Eng. Vol.33, 1903-4,page28

Franz Seiler.

"Apparatus for Metering Steam."

A. S. M. E. Vol.14, page751.

R. S. Boyntun.

" A Steam Meter."

Elec. Rev. London, 1904.Vol. 54, page 204.

C. E. Sargeant.

" Steam Meter."

A. S. M. E. Vol.26, page 246.

A. Gehre. -

" Steam Meter."

Zeitschrift des Ver. Deut. Ing. Dec. 8, 1900.

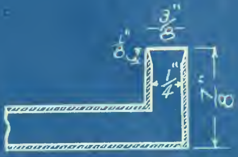


Figure No 1.

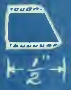


Figure No 2.

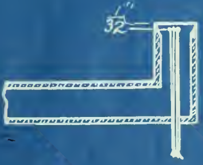
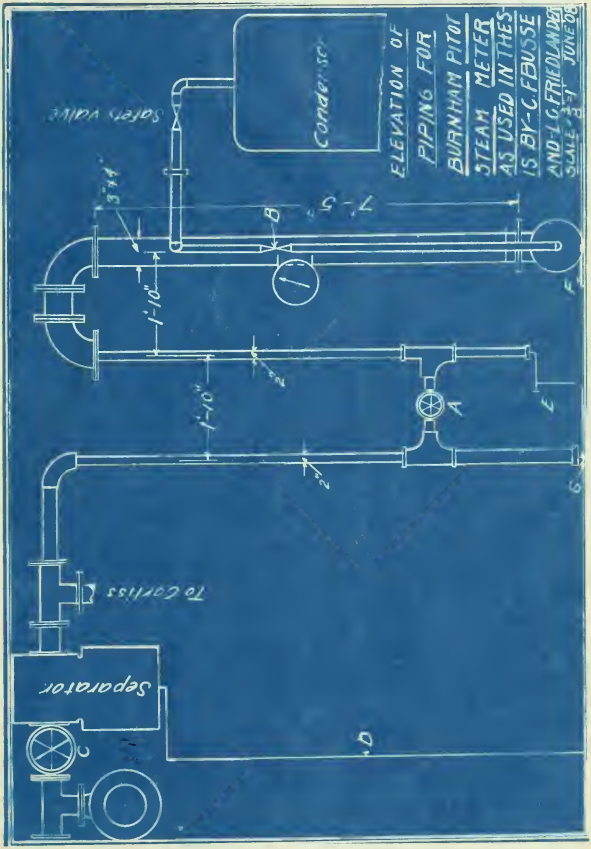
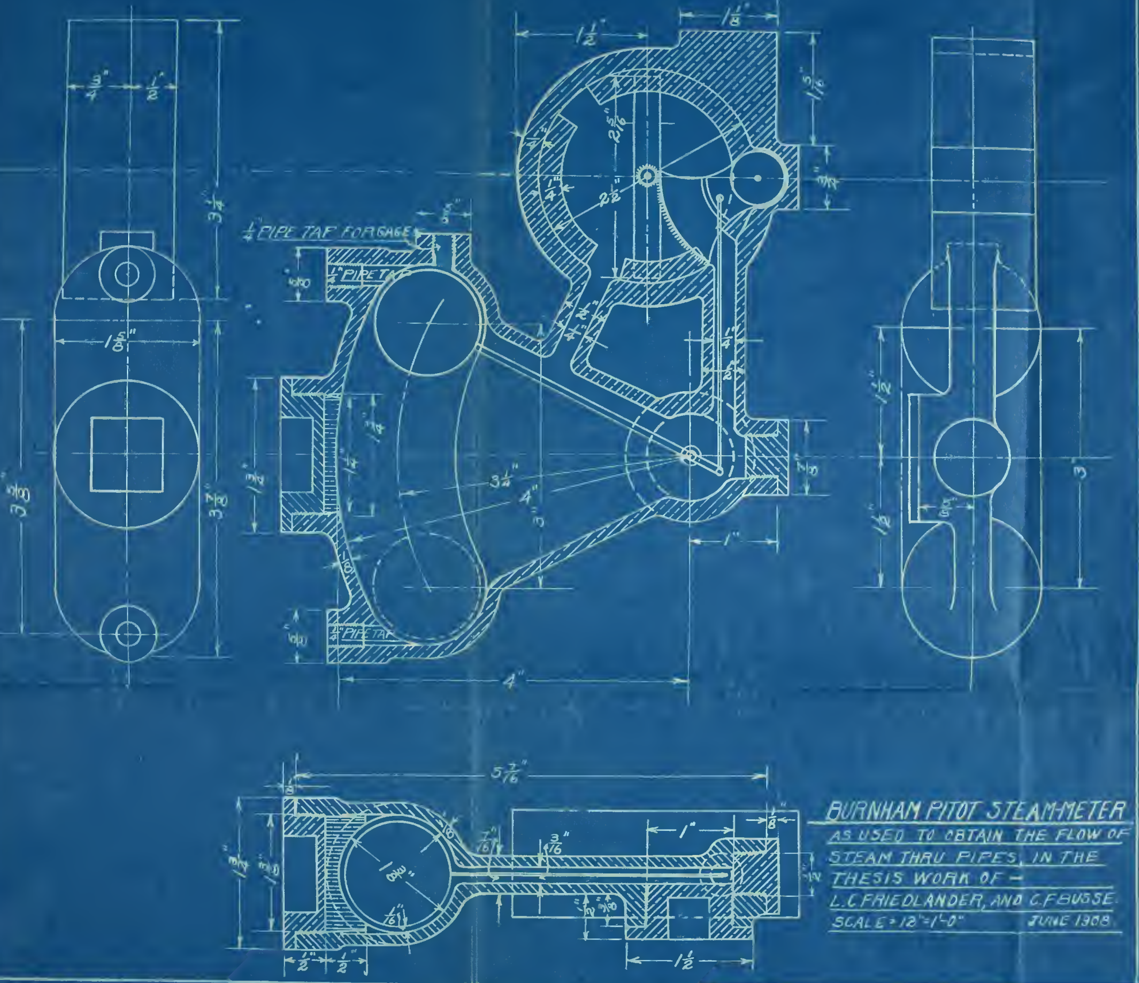


Figure No 3.

BLUE PRINT NO. 1.

Page 54.





BURNHAM PITOT STEAM-METER

AS USED TO OBTAIN THE FLOW OF
STEAM THRU PIPES, IN THE
THESIS WORK OF —
L. C. FRIEDLANDER, AND C. F. BUSSE.
SCALE = 12" = 1'-0"   JUNE 1908.